Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 366 188 A1**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: 89202634.5

(51) Int. Cl.5: G01R 33/36

(22) Date of filing: 18.10.89

(30) Priority: 24.10.88 NL 8802608

(43) Date of publication of application: 02.05.90 Bulletin 90/18

(84) Designated Contracting States: DE FR GB IT

(71) Applicant: N.V. Philips' Gloeilampenfabrieken
Groenewoudseweg 1
NL-5621 BA Eindhoven(NL)

(72) Inventor: Mens, Wilhelmus Reinerius Maria
c/o INT. OCTROOIBUREAU B.V. Prof. Holstlaan 6
NL-5656 AA Eindhoven(NL)
Inventor: Wardenier, Peter Hanzen
c/o INT. OCTROOIBUREAU B.V. Prof. Holstlaan 6
NL-5656 AA Eindhoven(NL)

(74) Representative: Scheele, Edial François et al
INTERNATIONAAL OCTROOIBUREAU B.V.
Prof. Holstlaan 6
NL-5656 AA Eindhoven(NL)

(54) **Magnetic resonance apparatus having an improved rf coil.**

(57) A magnetic resonance apparatus comprises an rf transmitter coil with individually or group-wise independently drivable antenna wires. For this purpose, a power amplifier is incorporated, preferably near each of the individually drivable antenna wires, which is connected, via an input network, to an rf supply source and on the other hand, for example, is connected to an antenna wire, for example, via a sliding contact. For generating a circularly polarized rf transmitter field a network may be incorporated which adjusts the phase per antenna wire.

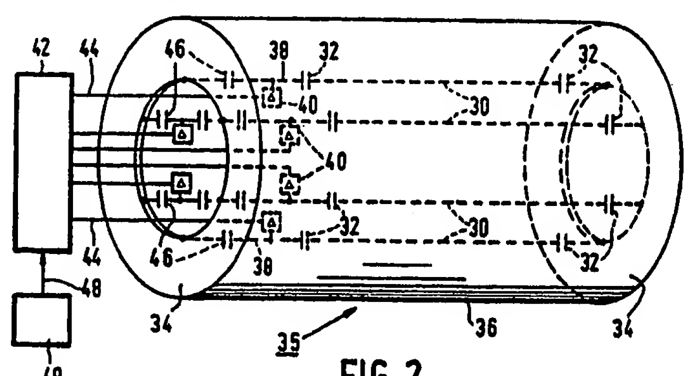

FIG. 2

EP 0 366 188 A1

Magnetic resonan e apparatus having an improv d rf coil.

The invention relates to a magnetic resonance apparatus having a magnet system for generating a stationary magnetic field, a gradient magnet system and an rf coil system.

Such a magnetic resonance apparatus is known from EP 213665. The apparatus described in said Specification comprises a bird cage rf coil which is built up from two ring conductors which are connected to a number of antenna wires which are mutually in parallel and with a symmetry axis. With a correct choice of impedances and reactances a spatial homogeneous rf field in the coil is generated with a standing closed cosine wave on the annular conductors.

US 4,712,067 describes an rf coil which is built up from a number, for example two, of saddle-shaped coils by which, with an adapted mutual coupling and a correct drive, a spatial homogeneous rf field can be generated in a mode which is dependent on the drive and mutual orientation of the current conductors. In this case also current conductors which are mutually in parallel and with a symmetry axis constitute active antenna wires of the coil.

When using such coils in the described form as transmitter coils for generating magnetic resonant signals in an object to be examined, the drawback of a low flexibility in the drive occurs in that the rf field within the coil is actually impressed, apart from the strength, by the geometry of the coil. Interfering counter fields are also often generated which can be compensated for only by extra power supply.

It is the object of the invention to avoid these drawbacks and for that purpose a magnetic resonance apparatus of the type mentioned in the opening paragraph is characterized according to the invention in that the rf coil system comprises a coil which has means for an individually controllable drive of antenna wires or sub-groups of aerial wires of the coil.

Since an rf coil according to the invention comprises independently drivable aerial wires a significantly greater extent of freedom in the field distribution is obtained and a significantly smaller excitation power often suffices.

In a preferred embodiment the rf coil comprises a number of straight conductors which are situated on a cylinder surface and extend in parallel with each other and with a cylinder axis and which are connected on each side via fixed capacities with a ring conductor and to which an rf source can be connected via a power amplifier. In particular, an input network having a resistor, a capacity and an inductance, is incorporated between the power amplifier and a supply to line from the rf source. The resistor hereof is connected, for example, to a voltage source for adjusting a quiescent current, while a capacitor, for example, is connected to an electrically conductive screening cylinder which surrounds the coil and which may also be constructed as a heat dissipating element. The power amplifiers which are formed, for example, by a MOS-FET transistor may be connected thereto via a readily heat conducting contact.

In a further preferred embodiment an output of the power amplifiers is connected to the antenna wires via a preferably externally adjustable sliding contact. The impedance of the coil can be adapted to an object to be measured by means of the said sliding contacts.

In behalf of circularly polarized rf fields, a circuit is incorporated in a further preferred embodiment for adjusting a phase shift, for example, given by the number of antenna wires, between successive antenna wires of, for example, a bird cage coil as described in EP 213665 of a transversal electromagnetic (TEM) coil as described in US 4,712,067.

A few preferred embodiments according to the invention will be described in greater detail hereinafter with reference to the accompanying drawing, in which

Fig. 1 shows a magnetic resonance apparatus comprising an rf transmitter coil according to the invention,

Fig. 2 shows an embodiment of such an rf coil,

Fig. 3 shows a circuit diagram for driving such a coil for generating a circularly polarized rf pulse, and

Fig. 4 shows an example of an amplitude and phase correcting network therefore.

A magnetic resonance apparatus as shown in Fig. 1 comprises a magnet system 2 for generating a homogeneous stationary magnetic field H, a magnet system 4 for generating magnetic gradient fields, supply sources 6 and 8, for the magnet system 2 and the magnet system 4, respectively. A radio frequency magnet coil 10 serves to generate a radio frequency magnetic alternating field and for that purpose is connected to a radio frequency source 12. For the detection of nuclear spin resonance signals generated by the radio frequency transmitter field in an object to be examined the rf coil 10 may also be used which for that purpose is connected to a signal amplifier 14. Another coil, for example, a surface coil, may also be used for detection. The signal amplifier 14 is connected to a phase-sensitive rectifier 16 which is connected to a

central control device 18. The central control device 18 further controls a modulator 20 for the radio frequency source 12, the supply source 8 for the gradient coils and a monitor 22 for display. A high-frequency oscillator 24 controls both the modulator 20 and the phase-sensitive rectifier 16 processing the measured signals. A cooling device 26 with cooling ducts 27 serves for the cooling, if any, of the magnet coils 2 for the main field. Such a cooling device can serve water cooling for resistance coils or liquid nitrogen and/or helium cooling for high field strength, superconductive magnet coils. The transmitter coil 10 placed within the magnet systems 2 and 4 encloses a measuring space 28 which in an apparatus for medical diagnostic measurements is wide enough to comprise a patient lying on a patient table 29. So a homogeneous magnetic field H, cross-sections of the object-selecting gradient fields and a spatial homogeneous radio frequency alternating field can be produced in the measuring space 28.

An rf coil according to the invention as shown in Fig. 2, in this case in the form of a transversal electromagnetic coil as described in US 4,712,067, comprises current conductors 30 which are connected to electric ring conductors 34 via capacitors 32. The ring conductors in this case nave the form of flanges forming part of a cylindrical housing 35 having a cylinder surface 36 for screening the rf field to be generated by the coil from interference fields. In the embodiment shown the cylinder 35 also forms a mass electrode for the antenna wires and may also serve as a heat dissipating element. Antenna wire parts 38 are connected, via a power amplifier 40 which comprises, for example, a MOS-FET transistor, to an amplitude and phase-controlling network 42 via preferably coaxial connection cables 44. Uncoupling capacitor 46 for uncoupling purposes are incorporated in the antenna wire parts 38. In this manner each of the antenna wires can be energized individually by means of the control network 42; however, several antenna wires may also receive an equal supply. The supply for various antenna wires may also differ in phase only. The control network is supplied via a connection cable 48 from an rf transmitter 49 corresponding to the rf source 12 in Fig. 1.

Fig. 3 shows in greater detail a part of a coil as shown in Fig. 2. An antenna wire 30 with a capacitor 32, flanges 34 and a cylinder surface part 36 of the coil are shown. Via a sliding contact a power MOS-FET 52 is connected to a part 38 of the antenna wire. The antenna wire part 38 is coupled, on the one hand via a capacitor 32, to the antenna wire 30 and on the other hand, via an uncoupling capacitor 46, to the flange 34.

A supply source from which a fixed voltage of, for example, 50 V can be applied to the antenna wire is incorporated for a fixed supply for the antenna wire. The MOS-FET transistor 52 is connected, via an input network 56 which comprises a coil 58 and a capacitor 60, to the amplitude and phase correcting' network 42 via a supply line 44. A quiescent current can be applied to the transistor 52 via a resistor 62.

Fig. 4 shows an example of an amplitude and phase correcting network 42. This is connected to amplifiers 40 as shown in Fig. 2 via the coaxial cables 44 and may be fed from the rf transmitter 49 via the coaxial cable 48.

The network itself comprises N sections 70 each having an L-C circuit 72 built up from an inductance 74 and two capacities 76. The number of sections equals the number of antenna wires or groups of antenna wires to be controlled individually and in practical cases is, for example, 6 to 12. For generating a circularly polarized rf field the amplitude to be applied to each of the coil wires is equal but for each of the wires mutually shifted in phase so that the amplitude wave hence rotates with the desired frequency over the antenna wires of the coil.

Claims

1. A magnetic resonance apparatus having a magnet system for generating a stationary magnetic field, a gradient magnet system and an rf coil system, characterized in that the rf coil system comprises a coil which has means for an individually controllable drive of antenna wires or subgroups of antenna wires of the coil.

2. A magnetic resonance apparatus as claimed in Claim 1, characterized in that a power amplifier is incorporated for each of the individually drivable antenna wires in the proximity of the antenna wire.

3. A magnetic resonance apparatus as claimed in Claim 2, characterized in that the power amplifier comprises a MOS-FET transistor which is connected, via an input network having an inductance and a capacity, to an rf supply source.

4. A magnetic resonance apparatus as claimed in any of the preceding Claims, characterized in that the rf coil comprises a number of antenna wires present on a cylinder surface about a central axis which are connected to ring conductors on each side via a capacity.

5. A magnetic resonance apparatus as claimed in Claim 4, characterized in that the ring conductors are constructed as flanges adapted to the cylinder.

6. A magnetic resonanc apparatus as claimed in any of the preceding Claims, characterized in that the rf coil is enclosed radially by an electrically conductive screening sheath.

7. A magnetic resonance apparatus as claimed in Claim 7, characterized in that the sheath serves as a mass for circuit elem nts of input networks and/or as a heat dissipating element for the power amplifiers.

8. A magnetic resonance apparatus as claimed in any of the preceding Claims, characterized in that the power amplifiers are connected to antenna wires via axially adjustable contacts.

9. A magnetic resonance apparatus as claimed in any of the preceding Claims, characterized in that a phase control device is incorporated in the supply for individually drivable antenna wires for driving with successive phase differences antenna wires for generating a circularly polarized rf transmitter field.

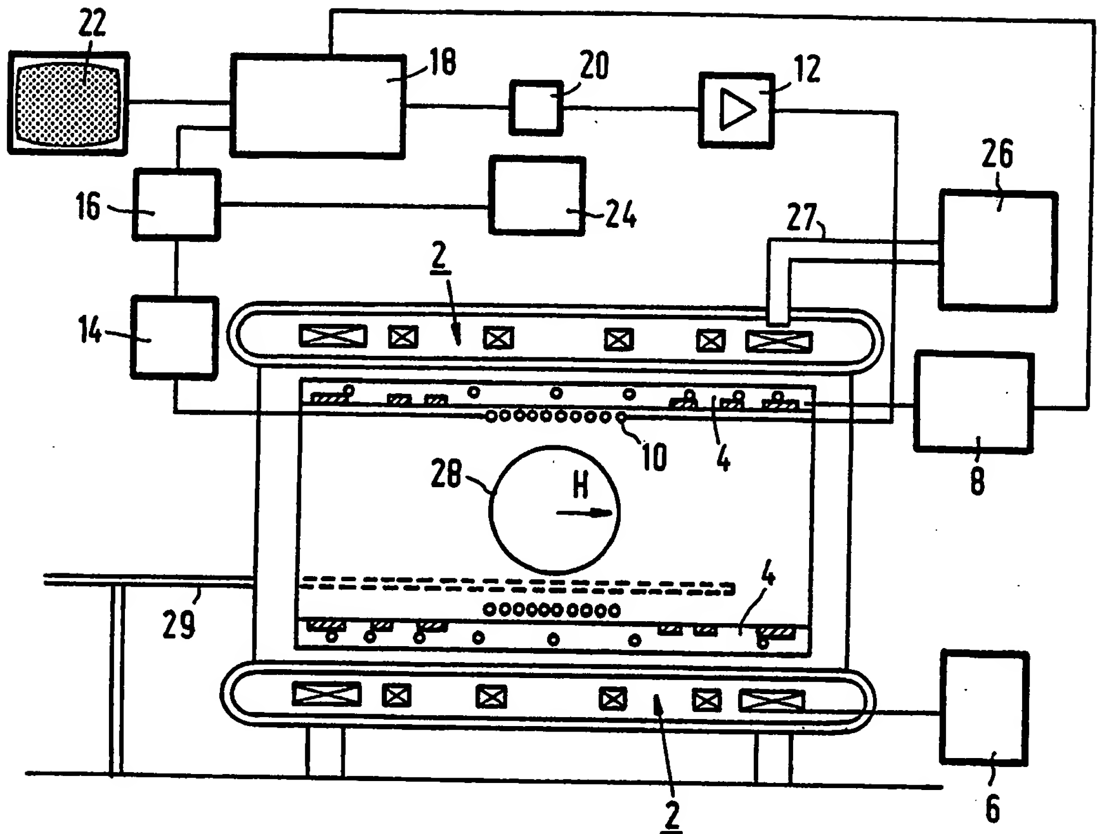
22
18
20
12
26
16
24
27
2
14
10
4
8
28
H
4
29
2
6

FIG.1

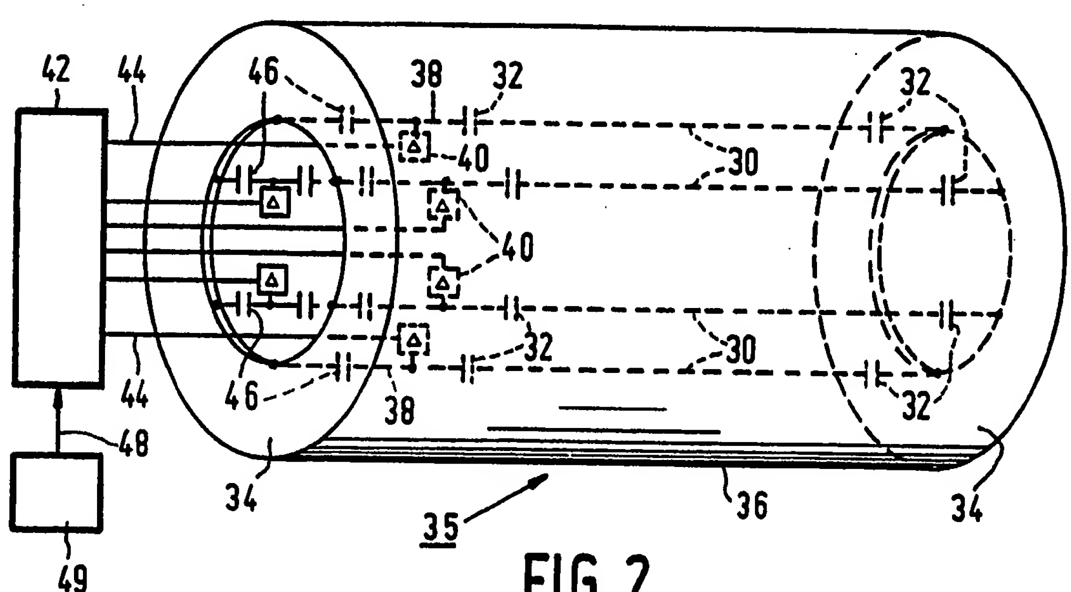
42
44
46
38
32
32
40
30
40
32
30
44
46
38
48
32
34
36
34
35
49

FIG. 2

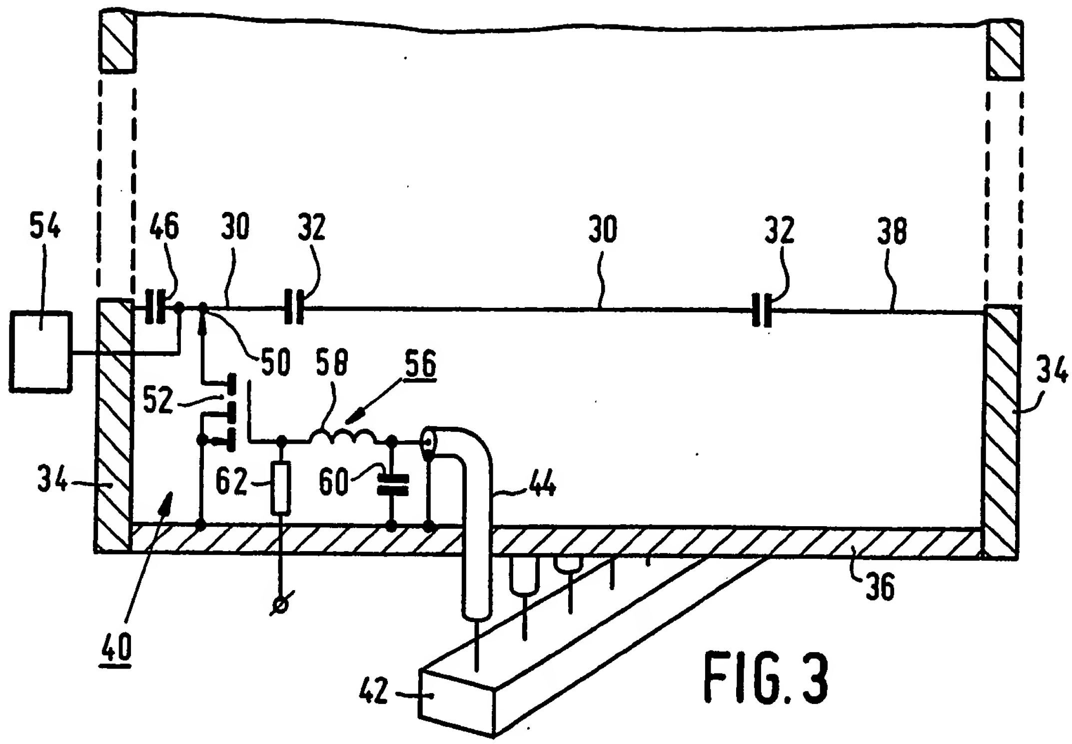
54
46
30
32
30
32
38
50
58
56
52
34
34
62
60
44
36
40
42

FIG. 3

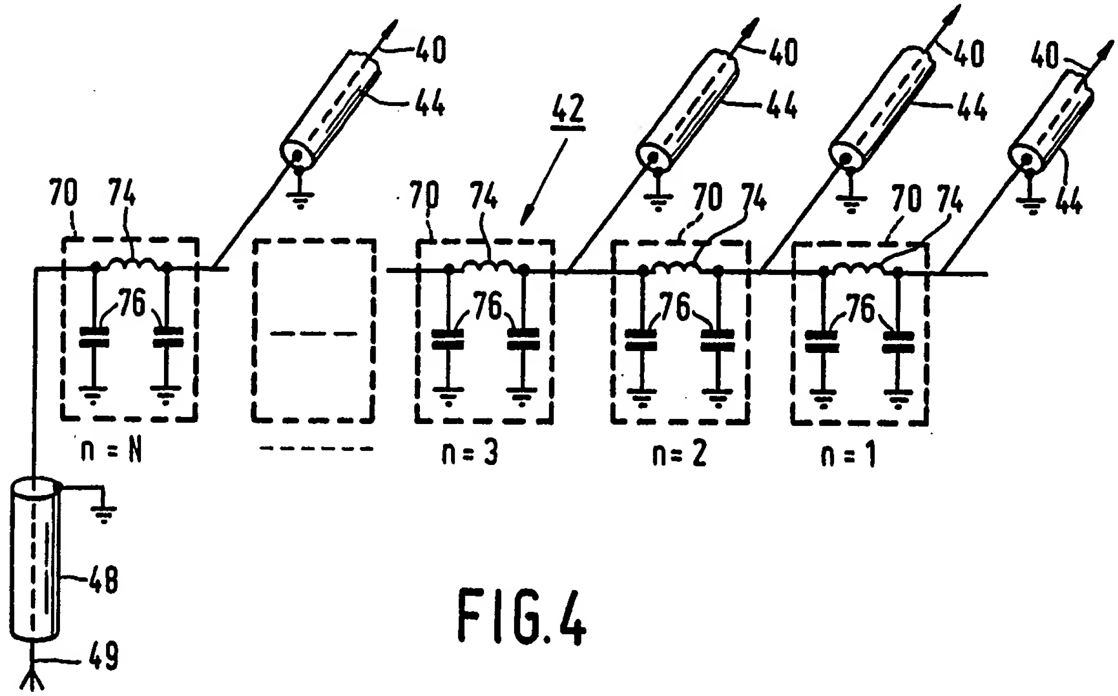
40
44
40
44
40
44
40
44
42
70
74
70
74
70
74
70
74
76
76
76
76
n = N
n = 3
n = 2
n = 1
48
49

FIG. 4